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WHAT THE PLANT PATHOLOGIST CAN AND OUGHT TO CONTRIBUTE TO A POTATO IMPROVEMENT PROGRAM[1]

J. G. LEACH[2]

University Farm, St. Paul, Minn.

At the summer meeting of the American Phytopathological Society held at St. Paul, Minnesota, June 25, 26, and 27, 1935, there was a round-table discussion on the subject "Potato-disease control through breeding for disease-resistance." It was the concensus of opinion at this meeting that breeding for disease-resistance offered one of the most promising outlooks for effective control of many of the most destructive potato diseases. As a result of this discussion a committee was appointed with instructions to stimulate encouragement and support for the efforts being made in this direction. The writer, as chairman of this committee, was invited to take part in this program devoted to potato breeding and has chosen the subject "What the plant pathologist can and ought to contribute to a potato improvement program."

In order to have the proper perspective it is necessary that we have a clear picture of the problem of potato improvement as a whole. For this reason I shall attempt a brief survey of the general potato improvement program.

That the potato needs improvement goes without question. With the exception of a few recently introduced varieties, most of the potato varieties grown commercially in the United States were produced more than 50 years ago and were selected for adaptability to soil and climatic conditions of a limited region in the northeastern section of the country. But potatoes are grown extensively in nearly

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[2]Chairman of the committee on potato improvement of the American Phytopathological Society. Other members of the committee are Drs. R. W. Goss, Donald Reddick and J. C. Walker.

every state in the Union under a wide variety of conditions. The growing of varieties unadapted to the varying soil and climatic conditions of the country is one of the chief reasons for the poor quality of many of our potatoes. The growing of relatively uniform high quality potatoes will not be accomplished until each climatically different region has superior varieties adapted to its own local conditions.

This does not mean that each local region must set up a separate breeding project to produce its own new varieties. Because of difficulties inherent in the nature of the problem this would be impossible in many regions even if desirable. One of the biggest difficulties in potato breeding has been the failure of most varieties to set seed. Some varieties will not set seed because of pollen sterility. Other varieties with fertile pollen will set seed only in regions with cool moist summers such as are found on the north shore of Lake Superior, in northern Maine, or other localities with similar climatic conditions. Recognized and well supported potato-breeding centers are first of all essential in a national program of improvement.

Although much of the actual breeding must be done in these breeding centers, a program of potato improvement confined to these localities would accomplish relatively little from a national viewpoint. Many problems of fundamental significance to a comprehensive improvement program could be dealt with only in a very limited manner, if at all. Selections for specific characters such as disease-resistance must often be made in limited regions where the disease in question occurs in epiphytotic proportions. New seedlings, produced by the plant breeders working in breeding centers, must be tested under a variety of conditions and for resistance to many different diseases. For this task is needed the cooperation of those plant pathologists in the different potato growing regions who are willing and able to contribute their time, effort, skill, and technique. In other words, by its very nature potato improvement is logically a national problem involving federal and interstate cooperation. The Division of Fruit and Vegetable Crops and Diseases of the United States Department of Agriculture, recognizing this fact, has, under the direction of Dr. F. J. Stevenson, initiated such a national potato improvement program. Considerable progress has already been made, but much more remains to be done, especially on those phases dealing with disease-resistance. It is a program that offers great promise and is worthy of the support of every one interested in the control of potato diseases.

Potato improvement by breeding new varieties has lagged some-

what behind similar improvements of certain other important crops. The lack of a practical potato-breeding technique has been the principal reason for this delay. The failure of most potato varieties to blossom and set seed under average field conditions is one of the chief limiting factors. This difficulty has been largely overcome by the establishment of breeding plots in regions where the summer temperature is uniformly low and the relative humidity high. A second difficulty lies in the failure of some varieties to set seed under almost any conditions because of pollen sterility. This problem has been solved, to a considerable extent, by pollinating those varieties that are pollen sterile with pollen of those rare varieties that have fertile pollen. The F_1 progeny of such crosses often produces fertile pollen, and by inbreeding and selecting those seedlings with fertile pollen a good supply of pollen-fertile breeding material has been produced. Thus, by inbreeding, selections with fertile pollen have been obtained, and the problem of potato breeding has been greatly simplified.

Pollen fertility is not the only new character that has been brought to the surface by inbreeding. Many of these inbred seedlings express other characters not shown by the parent varieties. For example, among such seedlings are found some that mature at least two weeks earlier than the earliest commercial varieties. Also some of the new seedlings have been found to be highly resistant to common scab, although the parent variety was very susceptible. These new seedlings, although desirable in some characters, are usually undesirable in others. In order to produce superior commercial varieties, it is necessary to cross the seedlings having one desirable quality with another seedling having a second desirable quality and then make further selections from the seedlings obtained from the cross. In other words, the desired characters are isolated from the heterozygous commercial varieties by a process of analysis termed inbreeding. When the various characters have been isolated by inbreeding, new varieties are produced by a process of synthesis or hybridization. This method is similar to that which has been used with marked success in corn breeding. The method promises to be even more valuable in potato breeding because, when once the desirable qualities are combined in one plant, they may be maintained indefinitely by vegetative propagation.

New species and varieties of *Solanum* introduced from Mexico and South America have also added much new breeding material with potentialities that have not yet been fully explored, but the

evidence indicates that valuable characters not possessed by our commercial varieties may be introduced into new varieties by hybridization. Plant breeders are beginning to realize that, in the process of domestication of our agricultural crops, it is probable that many valuable genes may have been left behind in the wild progenitors. With modern breeding methods it may be possible to use these "forgotten" genes in the synthesis of new and better varieties. This is a promising mode of attack, and the problem is of such great importance that no possibility should be overlooked. Rapid advances are being made in the theory and practice of plant breeding, and a sound practical technique potato breeding is now available. It is evident that we are on the threshold of a new era in potato breeding.

In the production of superior varieties such characters as yield, earliness, frost resistance, disease-resistance, tuber shape and smoothness, cooking quality, and many others must be considered. Without attempting to minimize the importance of any one of these characters it is safe to say that disease-resistance ranks among the most important of the desired characters. The potato suffers an average annual loss from diseases which is greater than that for any other important agricultural crop. This loss for the past decade averaged 19.8 per cent yearly or practically one-fifth of the crop. The responsibility of reducing this enormous loss rests squarely upon the plant pathologists of the country. It is a responsibility we can not shirk.

What are we doing to meet our responsibility? A great deal of good work has been, and is being, done to devise better methods of seed treatment and spraying. Better cultural practices have been devised, and improved methods of certification of seed stock are helping to keep down the losses from disease; but the limitations of these avenues of attack are evident to all who have struggled with the problem of potato-disease control. The one method of attack on the problem which has been used the least of all is that of breeding disease-resistant varieties. It is a method that promises a great deal. Plant pathologists, both individually and collectively, have a real obligation to see that the method is used to the best possible advantage. One of the aims of the committee which the writer represents is to make every plant pathologist realize this obligation.

The control of potato diseases by breeding disease-resistant varieties can be accomplished only through cooperation; cooperation not only between plant breeders and plant pathologists but among many groups of workers in different regions of the country. Cooperation of any kind is frought with difficulties and in order to avoid these

difficulties we often choose not to cooperate. But in this case there is no choice. By its very nature the problem is a cooperative one. The individualist working alone can accomplish relatively little even for his own local community.

Cooperation among plant breeders and pathologists should offer no difficulties. In the early days of the two sciences a small number of pioneers made significant contributions in the combined fields, but today there are few who would undertake to master both techniques and to handle personally all aspects of a program of breeding potatoes for disease-resistance.

Some pathologists may be reluctant to take part in a cooperative potato improvement program for fear that there may be restrictions on the diseases with which they may work. It is true of course that most pathologists would be somewhat restricted because of the soil and climatic conditions of their locality, since these conditions influence the prevalence of potato diseases; but it is the opinion of this committee that no arbitrary restriction should be recognized. A certain amount of duplication should be considered not only inevitable but also desirable. The benefits gained from differences in viewpoint and methods of attack, the facts to be learned from tests under different soil and climatic conditions, and in the possible presence of different physiological races of the pathogene would more than balance the disadvantages of duplication of effort. There is additional value in the stimulus gained from competition that should not be overlooked.

What are the more specific possible contributions of the plant pathologists to a potato improvement program? The primary function of the pathologist should be to test inbred and hybrid seedlings for resistance to specific diseases. Two general types of tests should be made. First a test of inbred seedlings or seedling families with the view of discovering suitable resistant breeding stock. These tests, to be effective, must be made under epiphytotic conditions, either natural or artificial, where approximately 100 per cent infection can be obtained. Otherwise it will be impossible to distinguish between escapes and truly resistant seedlings. Resistant seedlings discovered in these tests will be used by the plant breeders for crossing with other desirable seedlings, and the progeny of these crosses will have to be tested in a similar manner. If any of these hybrid seedlings prove resistant to the disease, they may also be of sufficient promise to justify more extensive tests for commercial adaptation. They would then be increased and tested out on a larger scale for general adaptability under a wider range of conditions. This would constitute the second type of test.

The first type of test would, in most cases, require a special study of the technique of producing uniformly heavy epiphytotics of the different diseases. Such technique has been worked out for only a few potato diseases. The working out of such technique is the task of the pathologist.

It would also be the responsibility of the pathologist to study the nature of resistance to the disease in question and to determine the extent of its variability under different environmental conditions.

Experience in breeding cereal crops for disease has shown that there may be more than one kind of resistance to the same disease by the same crop. Failure to recognize these types of resistance often seriously handicaps the breeding program. There is also evidence that resistance to many diseases is relative and not absolute and that the degree of resistance is greatly modified by environmental conditions. The significance of physiological specialization in plant pathogenes in a program of breeding for disease-resistance is now generally recognized. These facts are of great significance in the improvement program and involve important contributions that the pathologist can and should make.

The pathologist should also cooperate closely with the plant breeder in making special studies in the manner of inheritance of the factors for resistance to the various diseases. The same skillful technique in producing heavy epidemics is just as important in a study of this nature as it is in the selection of disease-resistant parental material

When a new variety is produced and selected on the basis of resistance to a specific disease, it should be remembered that its resistance to some other disease may also have been modified. The new variety may be more susceptible to some other disease than are our present varieties. There is always the possibility of increasing the destructiveness of a minor disease by introducing a more susceptible variety. This is not merely a theoretical possibility. It has happened in other breeding programs. To minimize this possibility, new varieties should be tested for resistance to as many diseases as possible before they are finally introduced to the public. Failure to do this may result in much embarrassment, disappointment, and waste of effort.

This also raises the question whether it is worthwhile to introduce a new variety that is more susceptible to the generally prevalent diseases than the varieties that we now have, although the new variety may be superior in some other character. This question probably would have to be answered for each individual new variety, but it would seem that it is the business of the pathologist to determine the

resistance of new varieties and to devise methods of doing it without awaiting the slow and often costly method of practical experience.

In conclusion the essentials of this discussion may briefly be summarized as follows:

1. The potato needs improvement. Improvement through breeding has been slow because of certain natural difficulties inherent in the nature of this crop. Modern plant breeding methods have largely overcome these difficulties and have provided a practical potato-breeding technique.
2. The potato crop suffers an average annual loss from disease greater than that for any other important agricultural crop. Disease control through development of disease-resistant varieties offers one of the most promising means of reducing these losses. Plant pathologists, both individually and collectively, have a definite and distinct obligation to see that this method is used to the best possible advantage.
3. Potato improvement, by nature, is both a local and national problem. It can be accomplished effectively only through cooperative effort on a national scale. Such a national potato improvement program has been under way for several years, but it is worthy of more adequate support, both scientifically and financially, than it has been receiving.
4. The extent of the success in potato-disease control through potato breeding will depend upon the extent to which plant pathologists take an active part in the improvement program. The plant pathologists can contribute much to such a program and he has a moral obligation to do so.
5. The principal contributions that the plant pathologist can and ought to make to the improvement program are:

   First. The development of techniques whereby relatively large populations of inbred seedlings may be subjected to practically 100 per cent infection by each of the important potato diseases.

   Second. The use of these techniques in the selection of suitable breeding stock resistant to the various potato diseases.

   Third. The testing in a similar manner of hybrid seedlings for the purpose of selecting desirable disease-resistant commercial varieties.

   Fourth. The testing of hybrid seedlings for the purpose of learning the manner of inheritance of resistance to specific diseases.

Fifth. The study of the nature of resistance to each of the important potato diseases and the degree of variability under different environmental conditions.

Sixth. The determination of the extent of physiological specialization of the various potato pathogenes and its significance in the breeding procedure.

Seventh. The study of any other pathological problem that may have a bearing on the breeding program.

CULTURAL AND STORAGE RESEARCH WITH POTATOES[1, 2]

E. V. Hardenburg

Cornell University, Ithaca, N. Y.

In briefly summarizing the research studies made during the current year which bear on the general subject of potato culture and storage, the author acknowledges that these terms are used in the broad sense. For convenience, culture has been made to include such topics as ecology, seed, varieties and cultivation and the summary is treated under these general headings. Consideration is also given to storage investigations. Such foreign publications as are not referred to in the discussion are included as citations in the appendix. The summary is not claimed to be complete and apology is offered to those authors whose published work may have been omitted.

Ecological

Ensign (12) correlated dates of planting with yield in the Hastings and LaCrosse areas of Florida during the five-year period, 1927-1931. Although temperature and soil moisture conditions vary for each of these areas, he found that such planting dates as will result in stolon formation and tuber-set during favorable soil and climatic conditions are most favorable to yield. The two-weeks period from January 15 to February 1 proved to be the best time for planting, the critical period or the period of stolon formation coming about 35 to 40 days later. Soil moisture proved to be more important than temperature as a limiting factor during the critical period. At

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[1]Partial report of the Committee on Research of the Potato Association of America.

[2]Paper No. 140, Department of Vegetable Crops, Cornell University.

LaCrosse too little moisture, and at Hastings too much moisture is the difficulty. Insofar as Ensign's studies show that ecological conditions during the period of stolon formation are most important in determining yield, his work corroborates that of previous investigators. Bushnell (5), at the Ohio Experiment Station, contributed concrete evidence of the importance of soil aeration as influencing potato yields on heavy soils. On Wooster silt loam soil which had shown declining yields in spite of liberal fertilizer treatment, he aerated potato soil by the use of plain and perforated 4-inch tile laid directly beneath the seed piece. As a check, trenches were dug and refilled without tile in adjacent rows. The tile-aerated rows outyielding the untiled rows by an average of 54 bushels to each acre or nearly 16 per cent.

Werner (24) reported further on the effect of temperature, photoperiod and nitrogen level on tuberization. Plants were grown in greenhouse sand cultures with nutrient solutions varying only in nitrogen supply. Tuberization was accelerated when the days were shortened, or when the temperature or the nitrogen supply reduced. Each or any combination of these conditions resulted in the synthesis of carbohydrates in excess of that required for growth and respiration.

Seed

In an economic study of potato farms in Aroostook County, Maine, Schrumpf (20) in 1929 and 1930, found that certified seed gave a yield of 102 barrels to each acre as compared with 98 barrels for selected seed and 88 barrels for common seed.

Hardenburg (14) has reported the results of a four-year study of the effects of greensprouting seed potatoes on time of plant emergence, rate of growth, stem number, stolon number, tuber set and yield. He found that greening did not improve stands but did hasten germination and rate of early growth, increased stolon number and weight, and also tuber-set, decreased stem number, and increased yield by a significant margin in both Green Mountain and Rural varieties. No advantage accrued from greening the seed longer than two weeks.

Bushnell (6), at the Ohio Station, experimented with potato grader screens of different mesh to determine what mesh would best separate out one-ounce and two-ounce tubers for seed. The object was to get a uniform grade of 1-ounce tubers for planting whole and a uniform grade of 2-ounce tubers for cutting in halves. He found that the 1⅜ inch mesh was best for ounce tubers whereas a 1¾ inch

mesh was best for most two ounce potatoes. Both of these screens are only 1/8 inch smaller than the standard screens now commonly used.

A size of seed piece experiment conducted two years at the Georgia Mountain Experiment Station was reported by Bailey (1). Pieces varying from one-half ounce to two ounces planted 12 inches in the row gave yields increasing with size of piece up to the one and one-half ounce size. Thinning the plants in this experiment to one stalk resulted in more uniform tubers but reduced the yield appreciably. Bates (2), of England, after concluding that past experiments on the relation of seed spacing and size of seed piece to yield were not conclusive because of lack of statistical analysis, conducted a Latin square experiment in 1934. He used 1-80th acre plots replicated four times to compare large, medium and small seed spaced 12, 15, 18 and 21 inches. His results corroborate other experiments as follows: The total yield increased as the size of seed increased for any one spacing and increased uniformly from the 21 to the 12-inch spacing. However, the percentage yield of large tubers decreased with closeness of spacing and with increase in seed size.

Hudson and Woodcock (15), of New Zealand, reported results of a four-year experiment to test the effect of locality in relation to seed-potato production. Taking a given strain of seed of known virus disease content, they distributed it among growers situated at different altitudes on the South Island for multiplication. Samples of the resulting crop, were then assembled at the station for yield test and virus disease counts. In general, yields were in inverse relation to the incidence of leaf roll, the latter being closely correlated with the incidence of the green aphis (Myzus persicae) the previous year. Seed grown at the higher altitude points in South Island proved more satisfactory than the same strains of two varieties similarly grown at the Station farm at Ashburton.

During the past year Denny and Miller (10) have made further contribution to their pioneer work on shortening of the rest period of potato tubers. In view of certain adverse reports on the use of sodium thiocyanate for this purpose, these workers applied the treatment in different concentrations at different temperatures. Comparing 0.5, 1.0, and 2.0 per cent concentrations of this chemical applied to cut seed pieces for one hour previous to planting in greenhouse flats, the 1.0 per cent solution proved most satisfactory. The 0.5 per cent solution was not quite so effective, while the 2.0 per cent solution caused rotting of the seed pieces in 7 of the 24 tests. They also show a method whereby the sodium thiocyanate absorbed by the treated tuber can

be recovered up to 85 per cent of the total amount absorbed. They were unable to determine the cause for dissatisfaction with this method of treatment as found by other investigators.

The comparative value of irrigated and dryland-grown seed was again reported by Werner (26). A disease-free tuber line strain of seed was grown in 1928 under both methods and tested for comparative yield in several southern states during the years, 1929-1931. In no case was the difference significant, hence Werner concluded that seed production of virus free strains under irrigation does not impair seed value. The question of whole versus cut seed has been revived from the practical standpoint by MacLeod (16) of British Columbia. After growers had experienced poor stands from rotted cut seed pieces and declining yields, a four-year experiment was conducted to compare whole with cut seed taken from certified stocks. In each of the four years at different locations, whole seed gave the larger yield. The average difference for the entire experiment was 3.1 tons to each acre in favor of the whole seed. MacLeod did not indicate whether equal amounts to each acre of each kind of seed were used in planting the experiments. Werner (27) studied the comparative productivity of seed potatoes grown in different lengths and types of rotations in Nebraska. Although the seed from the more vigorous plants in the longer alfalfa rotations yielded somewhat higher when tested under uniform irrigated conditions, the differences were not very significant. To determine whether this increased productivity was due to a difference in composition in the seed tubers, analyses were made. Slightly more total nitrogen and less acid hydrolyzable polysaccharides were found in the more productive seed from the longer rotations. Werner and Zook (28) report results of studies designed to determine the feasibility of growing seed potatoes in the vicinity of the North Platte Substation. Time of planting, time of harvesting, early cutting of the vines, removal of diseased plants and type of storage were factors considered. At the end of the period, 1925-1930, it was concluded that satisfactory seed for this district could be produced by harvesting early to reduce virus disease infection and storing the crop in good cellar storage.

Varieties

Davidson (9), during the past year, has published an excellent monograph on the history of potato varieties of commercial importance in Ireland. About 30 varieties are described and discussed. His paper concludes with a list of the present most promising varieties in Ireland

and a chronology of 19 of the most outstanding varieties of the two hundred year period, 1730-1930.

Woods (29) reported results of feeding Idaho-grown Russet Burbank potatoes to guinea pigs as a source of vitamin C. She found, that when fed in generous amounts, Netted Gem potatoes are a good source of this antiscorbutic vitamin. New immature potatoes contained twice as much vitamin C as fresh mature potatoes. Common storage for three to eight months did not change the content of this vitamin to any marked degree.

Culture

Edmundson (11) at the Greeley, Colorado, Experiment Station reported the results of studies during the years, 1928-1931, to determine the effect of closeness of seed spacing on yield, hollow heart, growth cracks and second-growth tubers. He compared spacings of 8, 10, 12 and 14 inches for the Rural and the Triumph varieties. With both varieties total yields increased with closeness of spacing although there was little advantage from spacing closer than 12 inches. Hollow heart and growth cracks decreased as spacing decreased in the Rurals while the same was true of second growth tubers in Triumph.

Hardenburg (14) compared planting depths of 2, 4 and 6 inches in silt loam soil using both Green Mountain and Rural varieties in a four-year experiment. The 2-inch depth gave a significantly larger number of stems to each plant than the 4-inch depth. The 4-inch depth gave the largest number of tubers per stem, the increase over the 6-inch depth being significant. Similarly the 4-inch depth gave the largest yield of No. 1 potatoes. The 6-inch depth usually resulted in the smallest yield, the exception being in 1931 when the rainfall was subnormal.

Werner (25) compared fall with spring plowing for potatoes in Western Nebraska in 1933. Invariably spring plowing resulted in better stands and greater yields than did fall plowing. Two diskings proved better than one regardless of time of plowing and where only one disking was given, late disking was better than early. Effect of depth of plowing was also studied, the depths compared being 3 inches, 6 to 7 inches, and 11 to 12 inches. Yields increased consistently with each increase in depth plowed.

Storage

Stuart and Appleman (22) reported on nitrogen metabolism in stored Irish Cobbler and McCormick potatoes. In general, they found

very little change in nitrogen either qualitative or quantitative during five months of storage at various temperatures. Variable conditions of culture produced chiefly quantitative rather than qualitative differences in nitrogen distribution. Non-protein nitrogen was higher in the medulla than in the cortex which may have an important bearing on our method of cutting seed.

Thornton (23), at Boyce Thompson Institute, initiated a series of studies of the effects of varying concentrations of CO_2 in the presence of oxygen on stored non-dormant Green Mountain tubers. As the concentration of CO_2 increased, respiration, catalase activity, pH, reducing sugar content and sucrose also increased.

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POTATO NUTRITION AND SOIL FERTILITY STUDIES IN 1935*†

Ora Smith

Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

This report summarizes the work on mineral nutrition, fertilization and soil fertility as applying to the potato.

In comparing the value of calcium cyanamid and ammonium sulfate on a sandy soil Sherard (48) found that calcium cyanamid produced no injurious effects on potatoes when mixed with the soil two, four and six weeks before planting, even when applied at the rate of 492 pounds per acre. Calcium cyanamid produced 20 bushels to the acre more than did equal amounts of ammonia from ammonium sulfate. Calcium cyanamid also increased the pH value and replaceable calcium in the soil while ammonium sulfate decreased the pH and replaceable calcium. Parker (41) found that a good correlation existed between crop increase and the equivalent acidity of sources of nitrogen that do not leach readily when used on moderately to strongly acid soils. Inorganic materials, a water soluble organic and inorganic-organic mixtures of sim-

* Report of Research Committee on potato fertilizer and soil fertility studies.

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ilar equivalent acidity per unit of nitrogen produced similar increases in yields.

Fertilizer tests by Clapp, Myers and Timmons (17) and Clapp (18) during 1931-1934 on soils representing major potato producing types in the Eastern Kansas River Valley showed that a combination of nitrogen and phosphoric acid at the rate of 150 pounds to the acre of 15-30-0 fertilizer produced a profit more consistently than any other fertilizer tested. Nitrogen and phosphoric acid at the rate of 200 pounds of 11-48-0 to each acre returned the highest profits in years of high yields. Potash did not increase yields enough to pay the added fertilizer cost and nitrogen or phosphoric acid alone caused a loss in each of the three years tested. Crowther (21), working in England, found that calcium cyanamid, on the whole, was slightly less effective than sulfate of ammonia under those conditions. These results were for one year only.

Brown (8) found that maximum yields were obtained in Connecticut from an amount of fertilizer which supplied 75 to 100 pounds of nitrogen, 135 to 180 pounds of phosphoric acid and 90 to 120 pounds of potash to the acre. When potatoes alternated with a crop of clover and timothy, the omission of any of the three nutrients was much less serious than on the continuous potato plots. In rotation, the no nitrogen plots yielded 95 per cent of maximum and 50 pounds gave maximum yields. In the 14 experiments conducted for three years on four different soil series no significant effects were found in the growth and yield of potatoes from the addition of magnesium sulfate, dolomitic limestone or hydrated lime, although some of the soils were very acid (pH 4.7) and very low in soluble magnesia and lime. On two farms, however, lime seemed to be of some benefit as indicated by slightly better vine growth and larger yields of tubers.

Two years' results in Connecticut (20) in which potatoes have been grown on highly fertilized, old tobacco land show that the residual effect of former heavy fertilization was still in evidence. The average yield without phosphoric acid (271 bu.) was only two bushels less than the standard with 120 pounds of P_2O_5 to the acre while the no potash treatment gave only 254 bushels to each acre. With 60 pounds of nitrogen to the acre the yield was 255 bushels indicating that during a year of low yields the full rate of application of nitrogen (100 pounds) is not entirely utilized. The plot receiving no fertilizer of any kind during both years yielded 160 bushels to the acre in 1934 and 279 bushels in 1933. Additions of magnesia in 1933 gave some increases. However, unfavorable weather in 1934 caused yields to be so low that

the soil, although relatively low in available magnesium, furnished sufficient of this element for the crop. Applications in the furrow of 500 to 3000 pounds per acre of commercial fertilizer on the marl glade soil of Florida (23) showed that 2000 pound applications were superior to either 3000 or 1000 pound applications and that both the latter were better than 500 pounds. As the application increased to 2000 pounds to the acre the percentage of large No. 1 tubers increased. An application of 1000 pounds in the row, followed by side dressing with 500 pounds, slightly outyielded the 2000 pounds applied in the furrow at planting time.

On these same soils a comparison of 1000 and 2000 pound applications of commercial fertilizer with the nitrogen content derived 33 and 66 per cent from organic sources, showed the high organic nitrogen to be an important factor in yields at least when all was applied at planting. Equal yields were obtained from 1000 pounds of 66 per cent and 2000 pounds of 33 per cent organic. On the other hand 2000 pounds of 66 per cent far out-yielded either and 1000 pounds of 33 per cent yielded far less. As a source of nitrogen, nitrate of soda proved less satisfactory than sulfate of ammonia in trials where half the nitrogen was cottonseed meal and the other half either nitrate or sulfate. However, the control plots, with only 33 per cent of the nitrogen derived from sulfate of ammonia and the rest from guano and cottonseed, outyielded both the test plots. A comparison of synthetic, high analysis fertilizer with commercial low analysis fertilizer showed practically no difference in yields for three consecutive years on the same plots.

Gray (25) found that with the Tasmanian Medium Brownell variety grown in Tasmania there was no indication that sulfate of ammonia had much influence on the cooking quality of the tubers. The results of rather comprehensive fertilizer experiments in Maine are given for the 1934 crop year (34). In the rate of fertilizer application studies on the three year rotation (oats, clover, potatoes) the plots where no fertilizer was applied yielded 140 bushels; where 1500, 2000, 2500 and 3000 pounds of a 4-8-7 fertilizer was applied, the yields were 338, 436, 455 and 492 bushels, respectively. Of the three primary fertilizer constituents phosphoric acid was the least important; potash, the most important; and nitrogen intermediate in determining yields. Harrington (26) reported results of phosphate applications during 1934. Phosphorus showed its value by increased yields, better grade, better netting of the Netted Gem variety, hastened maturity, resistance to mechanical injury in handling, and decrease in the tendency of Triumphs

to crack. In some of the plots nitrogen, with phosphorus in the form of ammoniated phosphate, gave benefits in excess of phosphorus alone.

A summary of five years' results with potato fertilizers in Oklahoma (13) shows that the crop responded to applications of phosphorus to a larger extent than to nitrogen or potash. Results are reported of two years' of field experiments in three different parts of Europe (1) on cultivation of potatoes with the use of sylvite, KCl, carnallite and mixtures of KCl with sylvite and with waste sludges and residues obtained in the electrolytic production of metallic magnesium from carnallite. The presence of sodium salts in sylvite and carnallite does not increase their effectiveness with potatoes. Conversely, crude KCl fertilizers introduced under potatoes in the spring, because of their considerable contents of chlorine, at times cause such a decrease in the starch content of the tubers that the results are unsatisfactory in spite of the increased yields.

Kuhnke (31) showed that the starch content of tubers fell from 15.2 to 9.5 per cent when the application of muriate of potash was increased from 160 pounds to 5100 pounds to each acre. High applications of sulfate of potash did not decrease the percentage of starch so markedly. The higher applications of potash also decreased the yields. The depression of the yield and starch content, caused by excessive application of potash salts, had no effect on the quality of the seed which had been grown under these conditions.

Rohde (44) described the external appearance of potash deficient plants as well as microscopic structural changes brought about by lack of potash.

Pinn and Davis (42), working in Australia, found that when potash was applied to the soil about three months before planting that it gave the plants an earlier start and a better stand than when applied at the time of planting. Several months after harvest, tubers which had been fertilized with potash during the growing season had much longer sprouts than those receiving no potash.

Bushnell (14) has shown that potash is needed in large amounts on muck soils, but found no significant response from the other fertilizer constituents.

No difference could be seen between muriate and sulfate as sources of potash on the marl glade soils of Florida (23).

Ramsay (43), working in Australia, states that for some reason, not apparent at present, potash has failed to justify its inclusion as a manure for potatoes in the bulk of the soils devoted to potato production in Victoria. The greatest increases in yields have been brought

about by applications of 900 pounds of superphosphate and 100 or 200 pounds of ammonium sulfate.

The effect of organic matter on yield in Aroostook County, Maine (34) was shown as follows: stubble only, yielded 411 bushels; one green manuring crop yielded 450 bushels; two green manuring crops yielded 493 bushels; one green manuring crop plus 6 tons of straw yielded 537 bushels; and one green manuring crop plus 20 tons of manure yielded 567 bushels to each acre. The green manuring crop used was a mixture of oats, peas and vetch. Each plot received 2000 pounds of 4-8-7. Twenty tons of manure to the acre in addition to 2000 pounds 4-8-7 increased the yield from 359 to 523 bushels to each acre. Bushnell (40) showed that chopped corn stover added to potato plots at the time of spring plowing increased the yields as follows: none added, yielded 352 bushels; 9 tons, yielded 395 bushels and 18 tons yielded 461 bushels per acre. This is the fourth season that coarse organic matter in one form or another has distinctly increased potato yields.

A comparison of 4-8-3, 4-8-5, 4-8-7, 4-8-10 and 4-8-12 fertilizers both with and without added magnesium was made on three farms in Aroostook County (34). The 4-8-10 produced the highest yield in the series without magnesium and the 4-8-12 produced the highest yield in the series with added magnesium. Dolomitic limestone was about as effective as more soluble sources of magnesium such as kieserite or double sulfate of potash-magnesia. When potato fertilizers containing various proportions of potash were used, both with and without magnesium, it was observed that the increases in yield due to added magnesium were greater with fertilizers either lower or higher in potash than with fertilizers containing 7 per cent potash. This appears to indicate some relationship between potash utilization and the magnesium content of the fertilizer.

The study of the effect of small amounts of manganese, copper, iron, zinc and nickel in potato fertilizer indicates that some of these elements may have stimulating effects under certain conditions but may also have depressing effects under other conditions. Results of experiments in Florida (23) in the marl glade soils show that plots which received no manganese for three years ranked lowest in yield followed by the plots which had been two years without manganese but had formerly received applications. Plots receiving manganese every year were higher than those not so treated. An application of 100 pounds per ton of fertilizer slightly outyielded either 50 pounds or 200 pounds. The yields of No. 2 potatoes were independent of any manganese treatment and the No. 1 tubers less than two and one-half

inches in diameter showed very little correlation. Tubers of more than two and one-half inches in diameter showed a steady increase with each increase in amount of manganese applied or with recency of application.

Addition of agricultural gypsum at the rate of 1000 pounds to each acre increased the yields consistently by approximately 10 per cent, but this was hardly more than enough to pay for the cost of the gypsum.

Carolus (16) found that on the lighter soils of Virginia, dolomitic limestone gave the higher yields and on the dark heavier soils the soluble salts of magnesium such as kieserite and sulfate of potash-magnesia were best. Magnesium deficiency is more marked at the lower pH because part of the magnesia absorbed at this pH (4.4) had to function in the plant as an aid to calcium due to the low calcium content.

Tests in Connecticut (19) on six farms including four soil series for two years show that no significant increases have been obtained from additions of magnesium. Eaton (22) describes the potato plant as semitolerant to injury by relatively large quantities of soluble boron in the soil solution.

Hester (29, 30) has studied the effects of lime on potato production in Eastern Virginia. Most of the added lime is soon converted to the soluble form as sulfates, chlorides and nitrates. The soils had a higher pH in winter than during the summer. The effect of quality of lime on soil reaction and the effect of lime on yields also were discussed.

In Maine potato fertilizers, with varying degrees of residual acidity, were compared (34) with similar fertilizers neutralized with either dolomitic or calcium limestone. The 1934 results indicate no superiority of neutral over acid fertilizers under the conditions of the tests.

The range in yield between the poorest and best of eight different fertilizer placements was 53 barrels to the acre with single strength fertilizer and 46 barrels to the acre with double strength. The highest yield for both strengths was obtained with fertilizer placed in narrow banks two inches to each side and slightly below the seed pieces. The single strength gave the lowest yield when mixed thoroughly with the soil below the seed piece and the double strength gave the lowest yield when placed in a four to five inch band about one inch below the seed piece.

Continuing the fertilizer placement studies in 1934 the results of Brown and Cumings (10) show that, in general, side placement gave

higher yields than fertilizer applied either under or over the seed piece, whether mixed with the soil or in bands.

On the other hand, on the marl glade soils of Florida (23) the placing of the synthetic fertilizer under the seed piece in the furrow gave slightly higher yields than placing it in narrow strips on each side of the seed piece.

Werner (50) found that withholding nitrogen from the nutrient solution or supplying only 10 per cent of the complete amount delayed tuberization for a short period only, but caused a great reduction in the number and weight of tubers. Other levels of nitrogen supplied at various stages in the growth of the plant were also studied in connection with various levels of temperature and photo-period.

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EFFORTS TO STABILIZE THE POTATO INDUSTRY IN CANADA

John Tucker

Central Experimental Farms, Ottawa, Canada

The Natural Products Marketing Act

The Act was assented to on July 3, 1934. This legislation is designed to deal with interprovincial and export trade and provides permissive powers which, when exercised, become law. These powers are centered in the Governor in Council, the Minister administering the Act, a Dominion Marketing Board and local boards which may be created under the Act. The Dominion Board is created to advise the Minister of Agriculture in the administration of the Act. The powers conferred by the legislation are granted to the Dominion Board and the Board is empowered to delegate these powers to local boards set up by producers or persons engaged in marketing, or by the two groups jointly.

A local board cannot engage in marketing as the powers conferred provide only for the regulation of marketing; nor can it restrict production or fix prices. It may, however, designate an agency through which the products may be marketed. In practice, the agencies designated have been the existing agencies that are engaged in marketing. It has the authority to regulate the time and place at which the product may be marketed and the quantity, grade or quality that may go forward to any market at any time.

Provincial marketing within a province is under the jurisdiction of the province and in order that a product may be the subject of regulations under the Natural Products Act, part of it must move to export trade or outside the province of production. Most of the provinces have passed enabling legislation and where this has been proclaimed, a scheme for the regulation of interprovincial trade, may be given additional powers under the Federal Act.

The keynote of the Federal legislation is local administration and control; the local board must be elected by the industry. The Dominion Board acts in a supervisory capacity, but can withdraw the powers given the local board if they are not used in a fair and equitable manner.

The Eastern Canada Potato Marketing Scheme

The instrument for the creation of a local board is called a "scheme." The petition for a scheme must come from a representative group engaged in the production or marketing of the product. The Dominion Board reviews the scheme and amends it if necessary to conform with the requirements of the legislation. It may then be published and hearings are held if necessary and the scheme again reviewed if any new suggestions are incorporated. The scheme may then be recommended to the Minister who may call for a vote to ascertain the measure of support back of the scheme, or may forward it direct to the Governor in Council for final approval.

As a result of the bumper crop of 1934, there was an increase of over eight million bushels of potatoes in the provinces of Prince Edward Island, New Brunswick, Nova Scotia and Ontario, as compared with the 1933 crop and, lacking organization, the growers were confronted with a demoralized market and inadequate returns for their potatoes. Meetings of producers and dealers were held at central points throughout the producing areas and the plan for a potato marketing scheme was endorsed. The scheme was launched under the title of The Eastern Canada Potato Marketing Scheme and was made effective in the four provinces on January 18, 1935. On April 30th, the scheme was amended to include the Province of Quebec.

Under the scheme it was expected that orderly marketing would be achieved primarily through control of the grades of potatoes entering the commercial channels of trade. Potatoes of inferior grades would not be allowed to glut the markets. Consignment

selling which contributed largely to the price demoralization would be ordered discontinued and sales would have to be made under firm contracts. The scheme also provided for the development of export markets and the encouragement of domestic consumption.

Large stocks were stored by dealers in January in anticipation of improved prices resulting from the action of the local potato board, but in spite of this the following improvements in prices paid to the growers, were registered after one month's operations:

Province	January 31, 1935	February, 1935
Ontario (per 90 lb. bag)	15–17 cents	35–40 cents
New Brunswick (per 165 lb.)	17–20 cents	35–45 cents
Prince Edward Island, Four largest dealers' reports (per bushel 60 lbs.)	8–10 cents	13–14 cents
Nova Scotia (barrels for export, including barrels) Per 90 lb. bag	75 cents 22 cents	$1.00 30 cents

The movement remained normal and the improved prices were maintained for a considerable time. The potato starch factories materially assisted by operating day and night, large quantities of potatoes were used for stock feed, but toward the end of the season it was obvious to many of the growers located in the Eastern districts far removed from the larger consuming centers, that there would be no possibility of disposing of their crops under conditions then prevailing and some changes had to be made in regard to consignment selling. The scheme in full operation undoubtedly had a very steadying influence on the markets and it would have been even more beneficial had it been started at the beginning of the marketing season instead of toward the end of January.

The acreage of potatoes in Canada in 1935 was the smallest planted in 20 years. The yields were also below average because of seasonal conditions. As a result of the exceptionally short crop harvested and the fact that the ruling prices are considered satisfactory to both producers and consumers, the Potato Board has decided that it is not expedient for it to function during the 1935-'36 season.

On the Pacific Coast, (the only other area which showed any interest in the marketing of potatoes under the Local Board scheme), a local board was approved in February, 1935, to administer the British Columbia (Interior) Vegetable Marketing Scheme. Prior to the submission of the scheme to the Dominion Marketing Board, the Provincial Marketing Board of British Columbia adopted a scheme to regulate the marketing, within the province, of vegetables produced in the coastal area. The Federal scheme was put into effect to supplement the Provincial scheme; to regulate the marketing of vegetables (potatoes only at that time) produced in the described area, that may be exported from the Province of British Columbia, and to grant authority for the collection of tolls and charges. The scheme appears to have worked quite satisfactorily there last season and is being continued again this season. This is now the only potato marketing scheme in effect under the Natural Products Marketing Act, in Canada; however, the machinery is ready, if called upon, to function again in Eastern Canada. The improved grades that were recommended by the Board are being maintained permanently.

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THE POTATO INDUSTRY AND THE SOIL CONSERVATION ACT

Will the Soil Conservation Act benefit the potato growers? This question is uppermost in the minds of many potato growers. In Virginia, for example, the General Assembly adopted a joint resolution requesting "that the Congress of the United States be memoralized to include Irish potatoes on the same basis with other agricultural commodities in any national program for the relief of agriculture". The Soil Conservation Act is not designed to assist the growers of any particular crop and since the potato is a soil depleting crop there is no reason to believe that it will not come under the Act.

The questions of immediate concern are the conditions and rates of payment. It has been suggested that payments be made upon that portion of the crop sold for consumption within the United States. Under this plan, according to H. B. Tabb, payments would be made on approximately 75 per cent of the 232,500,000 bushels which are usually produced. At a recent meeting of representatives from the Northeastern States, held in New York City, to consider the Soil Conservation Act, the following recommendations were made: For each acre of potatoes shifted to a soil maintaining crop the grower will receive payment of 20 per cent of the normal market value for the state, times the average potato yield for the farm. The maximum acreage for payment shall be 10 per cent of the 1935 acreage, with such adjustments as are necessary to correct for abnormal conditions in that year; or one acre, whichever is larger. If the land is shifted to a soil improving rather than soil maintaining crop, the rate of payment per acre shall be $5.00 greater.

It is questionable if any of these recommendations will be accepted in full and it is extremely doubtful if much can be done which will benefit the industry this year as most of the acreage in the southern states is already planted. It is important, therefore, that the growers do not overplant since, if this is done, low prices are almost certain to follow.